

Pediatric Medication Errors and Reduction Strategies in the Perioperative Period

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Anesthesia providers are regularly responsible for assessing, diagnosing, and determining pharmacologic treatment of a problem. This critical workflow often includes medication preparation. Decision making in anesthesia frequently requires rapid intervention, and caring for the pediatric population poses additional challenges, such as needing to quickly calculate the weight-based dosing of medications. The objective of this review article was to identify and describe themes related to pediatric medication errors associated with anesthesia. Additional goals of the review consisted of identifying and comparing various error reduction strategies with a primary goal of communicating the most effective methods to reduce medication errors in the pediatric population. Screening criteria were set, and 17 published scholarly articles meeting inclu-

sion criteria were evaluated using a systematic process. Common themes found leading to medication errors were incorrect dosing, incorrect medication, syringe swap, wrong patient, and wrong dosing interval. The most valuable and sustainable error reduction strategies found were standardized labeling, prefilled syringes, and 2-person medication checks. It is believed that this review will expound on the factors that can be controlled or minimized to decrease the incidence of anesthesia-related pediatric medication errors and facilitate implementation of risk mitigation strategies immediately into clinical practice.

Keywords: Anesthesiology, intraoperative pediatric medication errors, pediatric anesthesia errors, pediatric drug errors, pediatric medication error reduction strategies.

According to the US Food and Drug Administration (FDA), medication errors cause an estimated 1.3 million injuries each year in the United States, accounting for 1 death every day.¹ Medication error is defined as “failure in the drug to treatment process that leads to, or has the potential to lead to, harm to the patient and includes an act of omission or commission (drug not administered or administered late), substitution (incorrect drug administered instead of intended drug), repetition (extra dose of intended drug given), incorrect dose (incorrect concentration, amount, or rate of infusion of the drug administered), insertion (drug administered that was not attended at that time or at any stage), and incorrect route.”² Medication errors are of concern in the pediatric population due to the devastating implications for patients and are more likely to be life threatening in the pediatric population than in most adults. The increased risk in the pediatric population is due to the underdevelopment of their metabolism, which can affect medication clearance. Also, because of children’s smaller size, the need for meticulous calculation for weight-based dosing can lead to medication errors.³ Medication errors not only can have devastating effects on the patient but also can have distressing effects on the provider. Perioperative medication errors in the pediatric population by

anesthesia providers are a major concern, and reduction strategies are an ongoing challenge.

To formulate strategies to help reduce the occurrence of medication errors, one needs to first identify the most common perioperative medication errors. The purpose of this study was to perform a narrative literature review to characterize the frequency, type, and outcome of anesthesia medication errors among pediatric patients over the past 10 years. In this review we also sought to describe successful error reduction strategies described in the literature. Our research questions were: What are the main types of medication errors in the pediatric population aged 1 day to 18 years in the perioperative period? What mitigation strategies have had the best outcomes that can be implemented in our current anesthetic pediatric practice?

Methods

We conducted a narrative literature review on the topic of perioperative medication errors and reduction strategies in the pediatric population by anesthesia providers. Multiple search engines were used to find articles pertinent to this topic, including PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Google Scholar, MEDLINE, the Cochrane Library, and ClinicalKey databases. We considered relevant articles published between January 1, 2009, and July 15, 2019.

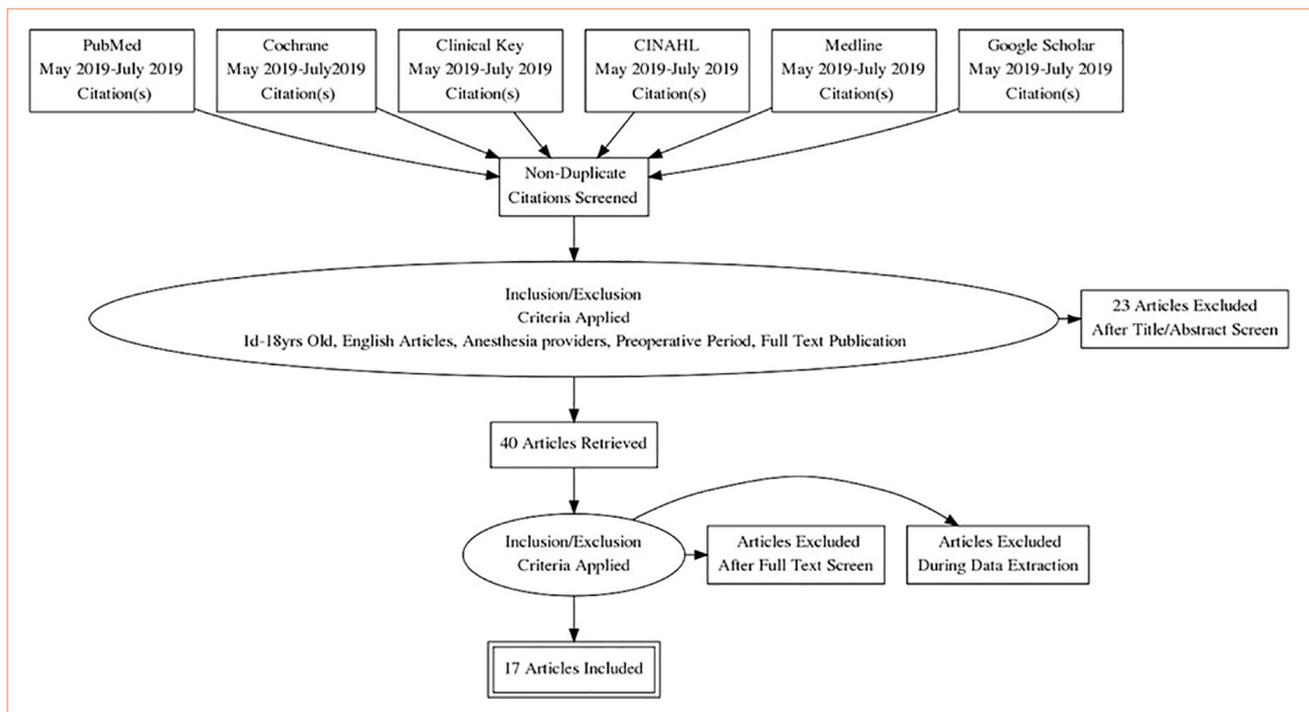


Figure. PRISMA Flow Diagram

Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health Literature; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

We defined *perioperative period* using the definition of Goodman and Spry⁴: “The perioperative period begins when the patient is informed of the need for surgery, includes the surgical procedure and recovery, and continues until the patient resumes his or her usual activities. The surgical experience can be segregated into three phases: (1) preoperative, (2) intraoperative, and (3) postoperative. The word ‘perioperative’ is used to encompass all three phases.” Study inclusion criteria consisted of a target population from 1 day to 18 years of age, articles printed in the English language, full-text publications, with medication errors and medication error reduction strategies performed by anesthesia providers and occurring in the perioperative period. Exclusion criteria included studies not published in English, not a full-text publication, did not take place in the perioperative period, did not involve the pediatric population of our specified age range, and did not involve anesthesia providers.

We identified search terms relevant to pediatric medication errors and reduction strategies perioperatively. The following search query was adapted to each database and was used to retrieve articles: *pediatric medication errors AND pediatric medication reduction strategies AND pediatric perioperative medication errors AND pediatric anesthesia errors AND intraoperative pediatric medication errors*. After our original search found 17 articles that met the inclusion criteria, we manually searched the references from the most applicable articles. Articles that were not published within the last 10 years, took place

outside the perioperative phase, or did not relate to pediatric anesthesia were excluded. After these articles were excluded, our search generated 18 articles.

The articles were scored using the Critical Appraisal Skills Programme Qualitative Checklist.⁵ This tool was chosen because it breaks down the methodologic approach to qualitative research into 10 detailed questions, which we used as a guide to thoroughly determine the quality of each article. There were 10 questions used to score each article on its quality. If the question was answered “yes” a score of 1 was given, “can’t tell” was given a zero, and “no” was given a zero. If the article achieved a score of 5 of 10, the article was considered of sufficient quality. After scoring each article, 1 was discarded, yielding 17 remaining articles. Data were extracted on the setting, intervention, problem, and major findings associated with pediatric medication errors with reduction strategies in the perioperative period involving anesthesia providers. A PRISMA flow diagram represents an illustrative flow of the references analyzed in the development of our narrative literature review (Figure). Finally, the 17 articles were reviewed and organized into themes.

Results

A summary of the medication errors evaluated is included in Table 1. A summary of the most common error reduction strategies appears in Table 2.

- **Data Analysis.** We first determined each medication error discovered in each article and then calculated

Example of medication errors	Examples identified in original texts	Percentage of each error compiled from our research
Incorrect dose	Dilution errors, calculation errors, incorrect interval	77
Incorrect medication	Phenylephrine vs ondansetron, similar looking ampules, similar sounding names	35
Syringe swap	Same color syringe, same size, same design, neostigmine vs succinylcholine	29
Inappropriate medication labeling	No label, no name, no concentration, wrong units, illegible, content differs from label, inconsistent label location, similar labeling	17
Known allergen	Distraction, interruption, fatigue	6

Table 1. Medication Errors in Pediatric Population During Perioperative Period

Example of error reduction strategy	Percentage of effective error reduction strategies compiled from our research
Standardized labeling	65
Prefilled syringes	53
Two-person check	41
Drug library/electronic-based references	35
Quality improvement safety analytics	35
Pharmacy support	29
Computer check system	24
Educating staff	17
Standardized anesthesia workspace	12
Zero-tolerance philosophy	12
Checklist	6

Table 2. Medication Error Reduction Strategies in Pediatric Population During Perioperative Period

a percentage to determine which errors occurred most often. After a review of the articles in our study, 70% (12 of 17 articles) reported medication errors involving incorrect dosing,^{1-3,6-14} 35% (6/17) were related to incorrect medication,^{2,3,8,10,15,16} 29% (5/17) were related to syringe swap,^{1,6,10,11,16} 17% (3/17) were inappropriate medication labeling,^{2,11,15} and 6% (1/17) were related to a known allergen³ (see Table 1).

The causes of the incorrect dosing were noted to be from incorrect dilution of a medication and errors in calculation of the dose. In regard to children, calculating the proper weight-based dose is critical, and the errors from miscalculation can be fatal. The primary cause of syringe swap was having a medication manufactured with similar labels. Various medications have the same color and design, such as ondansetron and phenylephrine. The outcome of swapping these medications can be and has proved to be fatal. For example, an 11-year-old boy underwent general anesthesia to drain an abscess of the ankle.¹⁰ While the patient was under anesthesia, the anesthesia provider administered what was thought was ondansetron; however, the provider mistakenly administered a concentrated 1-mL ampule of phenylephrine. As a result, this patient experienced a fatal heart arrhythmia following the administration of the phenylephrine.

Unfortunately, these vials look similar and were mistaken for one another, which cost a life in this tragic instance.¹⁰ High stress, fatigue, and distractions are found to be contributing factors that also can cause medication errors.

• **Outcome Measures.** Our outcome measures included the common themes found among the most common medication errors made. One of the most common themes found among medication errors was incorrect dosing of the medication due to calculation errors. Calculation errors were found to most frequently occur during the dilution of a medication. The second most common theme found was the administration of an incorrect medication. For example, ondansetron and phenylephrine have similar-appearing vials, which may cause one to be administered instead of the other, intended medication, ultimately leading to a medication error.¹⁰ The remaining common themes found leading to medication errors were syringe swap, wrong patient, and wrong dosing interval.² This information, along with identified characteristics that make the pediatric population most at risk, led to the formulation and implementation of medication error reduction. The implementation of medication error reduction strategies was evidenced to help reduce medication errors and improve safety in the pediatric population.

Our outcome measures also included the various medication error reduction strategies that were implemented in each study. From the literature review, standardized labeling was found to be the most effective error reduction strategy,^{2,6,8-13,15-17} followed by prefilled syringes.^{2,3,7,8,10,12-14,17} Other error reduction strategies included 2-person check,^{2,3,10,11,13,14,17} using a drug library/electronic-based references,^{2,3,7,8,12,17} using quality improvement and safety analytics,^{3,6,8,17-19} using pharmacy support,^{3,6,7,10,13} using a computer check system,^{3,8,15,16} articles educating staff,^{2,17,19} using a standardized anesthesia work space,^{11,17} using a zero-tolerance philosophy,^{3,8} and using a checklist⁹ (see Table 2). A zero-tolerance philosophy is generally considered to include a meeting in which practitioners who have not followed the institution's policy for medication administration can provide an explanation in an effort to help the team understand the problems involved. These meetings generally take place with the chief practitioner and provide opportunity for the chief to identify potential unsafe behaviors by the practitioner involved in the incident, which may possibly lead to consequences. The goal of this philosophy is ensuring patient and practitioner safety.³

• **Error Reduction Strategies Supported by Literature Review.** Patient safety is of utmost priority, and the National Academy of Medicine (formerly called the Institute of Medicine) is seeking strategies to prevent medication errors from occurring. Although anesthesia is among the leaders in patient safety, research findings suggest that high medication error rates in this field of practice still exist.¹¹ Studies have found medication errors to be responsible for more than 80% of scenarios that cause patient harm, and nearly all these scenarios were considered to be preventable.⁶

Throughout our research, themes were recognized describing the various medication errors routinely seen during the perioperative period. The addition of pharmacy support, a checklist, 2-person verification, pediatric anesthesia drug library on infusion pumps that includes dose ranges and forcing functions to double-check the patient's weight and appropriate dosages, and a zero-tolerance philosophy are some error reductions strategies that have been executed.^{1,3,9} Several of these medication error reduction strategies were implemented throughout various institutions nationwide and found to be effective.

The most valuable and sustainable error reduction strategies found were standardized labeling, prefilled syringes, and 2-person medication checks. Standardized labeling should be clearly identifiable. One way this can be achieved is by using a specific color for specific drug types. An example provided in one of the articles is that opioid medications were color coded with light-blue labels.¹⁷ An additional way to achieve standardization of labels is through a distinguishable font. A distinguishable font includes font size and style for ease of readability. In

addition, having clear organization of the wording on the label helps providers differentiate between medications. Label placement is also important, and it was found that having it lengthwise on the syringe helps improve medication identification. By performing lengthwise label placement, studies have shown that there is likely a reduced rate of syringe swap and medication errors relating to a decrease in cognitive load.¹¹ The FDA has changed its standards over the last decade on the labeling of medications. Because of these changes, hospitals are now incorporating bar codes in their labels for all drugs and biologics. Incorporating bar codes and medication labels is a safety measure used to ensure the correct patient receives the correct medication at the correct time.¹⁵

The second most valuable and sustainable error reduction strategy was prefilled syringes. According to Shaw and Litman¹⁶: "Prefilled syringes can be prepared either at the drug manufacturer's site of production, by a third-party medication distribution centre, or by a hospital pharmacy under similarly accurate and sterile conditions." The theory behind prefilled syringes is that they eliminate errors that come from provider preparation during the reconstitution and dilution of medications and they provide the most accurate dose of medication. Also, in an emergency situation, prefilling syringes makes medications more readily accessible and reduces errors that are associated with providers preparing medications under stress. Although higher costs and limited shelf life are disadvantages to pre-prepared syringes, the quality controls completed during their preparation make these medications more precise and help reduce the rate of medication errors.¹⁷

The third valuable and sustainable error reduction strategy found was performing a 2-person check before administration of medication. These checks are completed by 2 individuals separately confirming the 5 rights of medication administration. These 5 rights are the right patient, medication, dose, route, and time. Two-person checks vs single-person checks were found as an effective method for preventing medication errors.

Discussion

Pediatric medication errors occur in the perioperative setting for various reasons. Limitations of the studies include in this review involved data coming from a voluntary reporting system and manual chart review. This makes it difficult to establish the true rate of medication errors. Another limitation is implementing these reduction strategies at facilities nationwide and not just at specific hospitals. These medication errors are most likely underreported because of the fear of repercussions and unawareness of errors. Some of the factors that prevent healthcare providers from reporting medication errors is the fear of responses from patients, patients' family, physicians, and administration. Specifically, there is fear of

a negative attitude being developed toward the provider or the possibility of being sued. Developing a supportive atmosphere and adopting a no-punishment approach to medication errors have been shown to help improve self-reporting. In addition, a simplified reporting process for healthcare providers that is easy and convenient to use has been shown to improve self-reporting. The reporting of medication errors is important to identify reoccurring errors so they can be corrected and help improve overall patient safety.²⁰ Due to these limitations and factors, the estimate of the frequency of errors is not accurate. Research has shown an improvement in the incidence of pediatric medication errors with the implementation of various error reduction strategies. We believe as more quality improvement and safety analyses are conducted regarding pediatric medication errors in the perioperative setting, the incidence of errors will continue to decline.

After reviewing each article, we found that standardized labeling was the most effective reduction strategy, followed by prefilled syringes. The quality controls that are prepared on pre-prepared, labeled, and sealed syringes that come from either the pharmaceutical industry or the hospital pharmacy make the use of that medication more accurate, effectively reducing medication error rates. The limitation of pre-prepared syringes is the restricted shelf life and associated higher costs.¹⁷ Another limitation to error reduction is lack of self-reporting. This makes it difficult to determine the exact cause, how often errors are occurring, and where the gap lies in working to prevent such errors in the future. Furthermore, the level of implementation and acceptance of altering everyday practice with new policies and recommendations relies on how overburdened the healthcare providers feel with such changes.¹⁷

Additional research needs to be completed regarding medication error reduction strategies that have been effective and to find ways to successfully implement reduction strategies into current everyday practice. The implementation of these error reduction strategies would reduce the rate of current errors and prevent new errors, which would improve the overall quality and safety of the perioperative environment for the pediatric population.

Suggested areas for future work should be based on using methods for data collection other than self-reporting. Self-reporting leads to inaccurate data due to lack of providers disclosing their medication errors. A solution suggested is for providers to report all medication errors, not only those that cause patient harm. Furthermore, another recommendation is to have future studies conducted using a culture of no-blame drug error reporting and review system. Another method proposed was to use a retrospective chart review. It is important for the medication error reduction strategies discovered to be standardized and implemented nationwide vs at select individual hospitals. After implementation of these strategies, further studies should be performed to see if results can be gen-

eralized. Additionally, after medication error reduction strategies are put into effect, if errors continue to occur, it is suggested to expand research at a more individual basis regarding provider fatigue, burnout, and supervision.

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